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**Final Report for NRA-95-12-SL-032
NAGW-5103**

Title: A Novel, Poly-Etalon, Fabry-Perot for Planetary Research

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Proposed Duration of Project: 24 Months

Desired Start Date: 12/1/95

End Date: 6/30/97

A Novel, Poly-Etalon, Fabry-Perot Spectrometer for Planetary Research

PROPOSAL SUMMARY

Principal Investigator: Robert B. Kerr
Institution: Boston University

ABSTRACT

In an effort to develop a mechanically robust, high throughput and solid state spectrometer several liquid crystal Fabry-Perot etalons were constructed. The etalons were tested for spectral response, radiation resistance and optical transmission. The first year of this project was spent developing and understanding the properties of the liquid crystal etalons while in the second year an intensified all-sky imaging system was developed around a pair of LC etalons. The imaging system, developed jointly with SRI International represents a unique brassboard to demonstrate the use of LC etalons as tunable filters.

The first set of etalons constructed in year one of this project were tested for spectral response and throughput while etalon surrogates were exposed to proton radiation simulating the exposure of an object in Low Earth Orbit (LEO). The 2" diameter etalons had a measure finesse of ~10 and were tunable over five orders. Liquid Crystals exposed to proton irradiation showed no signs of damage.

In year two two larger diameter (3") etalons were constructed with gaps of 3 and 5 microns. This pair of etalons is for use in a high resolution, all-sky spectral imager. The WATUMI imager system follows the heritage of all sky, narrow band, intensified imagers however it includes two LC Fabry-Perot etalons to provide tunability and the ability to switch wavelengths rapidly, an import consideration in auroal airglow imaging. This work also resulted in two publications and one poster presentation.

The instrument will be uniquely capable, with superior throughput and speed, to measure optical airglow of multiple emission lines in harsh conditions.

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Year Two developments:

In year one the first 2" diameter LC etalons were developed, a broadband reflectivity coating was designed and etalon surrogates were exposed to proton irradiation. Testing of the initial LC etalons showed that it was possible to achieve a finesse of ~10 with a tunability of several orders. Additionally the radiation testing showed that liquid crystals could survive proton bombardment consistent with low earth orbit. The next step of this project was to move the etalons from laboratory curiosity to a brassboarded instrument. The broad success in the first year of this project allowed Dr. Richard Doe to provide additional monies via an SRI internal research grant to develop a all sky tunable imager based around two 80mm diameter LC etalons. This imager is designed to image both auroral emissions as well as a testbed to determine the efficacy of using such a tunable imager to detect human activity in areas covered with dense foliage.

Year two of this project resulted in both an expansion and a refinement of the LC etalon technology. The etalon driver electronics were enhanced to allow for more control of the etalon tuning, by including a voltage offset as well as fraction gain control we are able to tune the index of the liquid crystal in the etalon cavity with an order of magnitude more precision. Also a thermal stabilization system was developed and implemented by adapting the thermal stabilization system developed for diode lasers we can maintain etalon temperature to better than .01 °C. This imager system will be fielded in Sondestromfjord in early 1999, where it will be used to image both the Oxygen "red line" (630.03 nm) and the Sodium "yellow" line (589.6 nm).

System Design:

Two 80mm diameter etalon pairs with a surface flatness of $\lambda/200$ were purchased and coated with Indium Tin Oxide and the broadband dielectric coating developed in year one of this project. While it was possible to repeatably create a coating with the appropriate reflectivity, the absorption of the coating was highly variable and posed a problem in the development of the LC etalons. As the interference pattern created by a Fabry-Perot etalon is a function of mulitple bounces within the etalon cavity even a small amount of

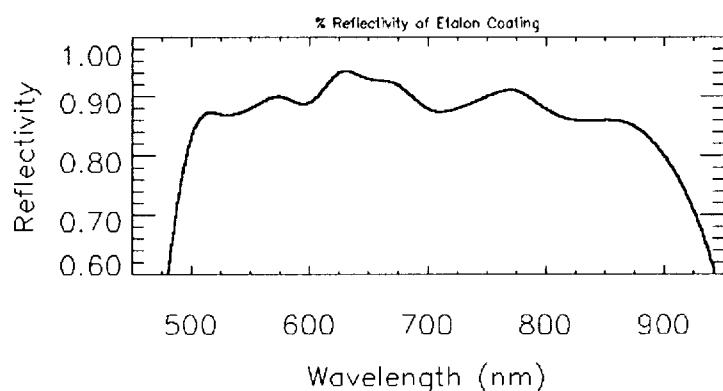


Figure 1. Broadband reflectivity curve of the all-dielectric

absorption in the reflective coating substantially reduces the transmission of the etalon. In order to implement LC etalons in an imaging system it is important that the transmission is comparable to extent narrowband interference filters. A new, all-dielectric coating was developed with the requisite reflectivities and importantly an absorption of near zero (Figure 1). The etalons were stripped and recoated with this new coating, and then filled with liquid crystal.

The LC etalons were constructed with gaps of 3 um and 5um for the two etalon WATUMI sytem. Figure 2. shows a model of the spectral range of the two etalon system. Figure 3. Shows a photograph of the constructed LC etalon.

Etalon Control:

The LC controller designed in the first year of this project was modified to include the ability to add a voltage offset as well as variable gains ranging from 1/16 to 1. A voltage offset is needed because the LC within the etalon does not begin to respond until the torque produced by the electric field is able to overcome the friction between the liquid crystal and the alignment layer. Typical voltage offsets are from 1-2 volts and is a

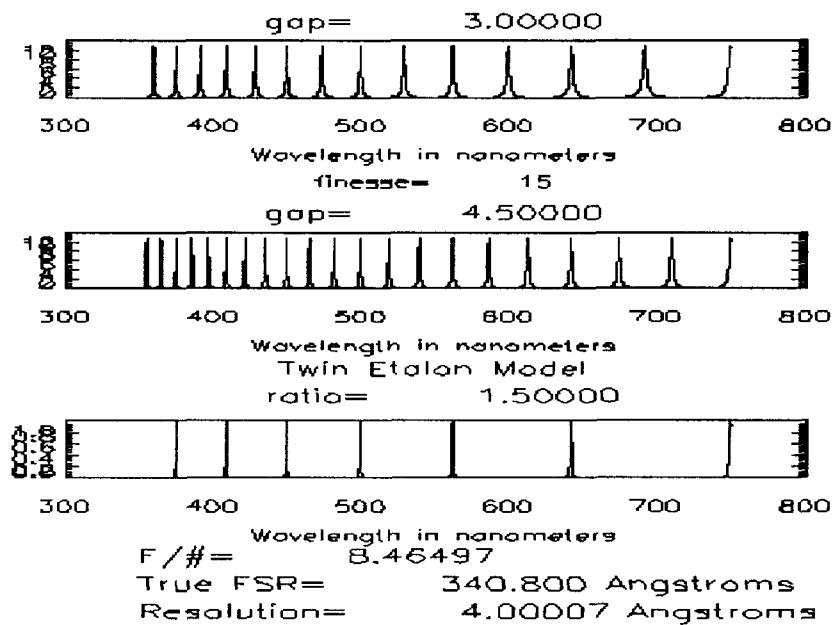
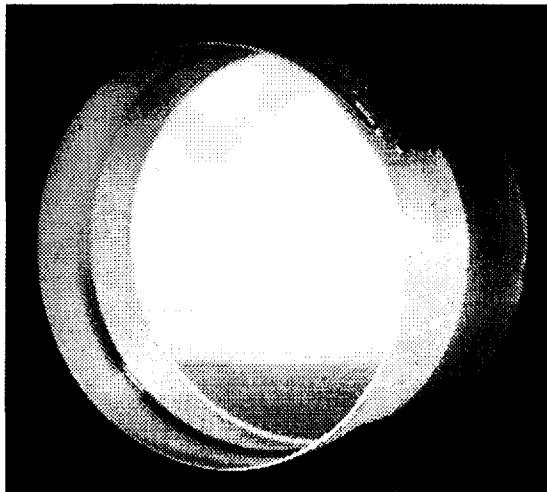


Figure 2. A model of the expected two etalon response.

function of the liquid crystal used. In year one it was found that the LC etalons could be tuned over the entire index range with an applied voltage that was less than the total range of the controller. In an effort to increase the precision of index control, variable gain feature was added to the LC controller. This variable gain allows the full range of the



D/A converter (12 bits) to be matched to the range of refractive index of the LC within the etalon cavity. Figure 4 is a photograph of this new LC controller in a rack mountable, anodized housing.

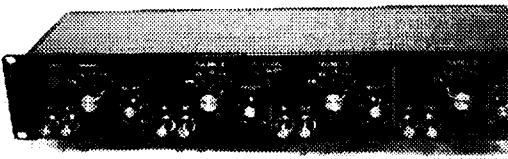


Figure 4. The newly improved 4 channel LC controller

The WATUMI system:

Figure 5 shows a schematic of the SSI/SRI tunable all-sky imager designed around two 80mm diameter etalons. The design incorporates an all-sky lens and a pair of Nikon relay lenses that act as a collimator and reimager. Sandwiched between the two relay lenses are two 80mm diameter etalons, an image intensifier and a broadband order-sorting

interference filter. This design is similar to other all-sky imagers however the two LC etalons provide a wavelength agility unsurpassed in other systems. The WATUMI system has a wavelength resolution of better than 1.5 nm, a continuous tuning range of 200 nm and a photometric sensitivity of 5 R-s (Doe et al., 1998). All the optics are encased in a temperature stabilized housing and we are expecting to deploy the system to the Canadian arctic in the boreal winter of 1998/1999 to image polar cap airglow emission features.

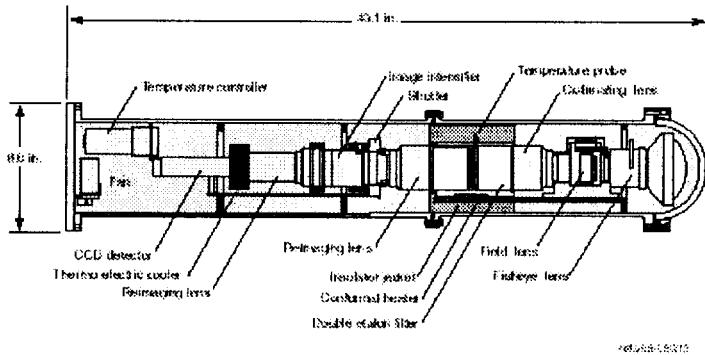


Figure 5. A schematic of WATUMI

Publications resulting from this work:

Doe, R., A. J. Noto, W.J. Schneller, and R.B. Kerr, "A wavelength-agile imager for arctic aeronomical research", (poster) CEDAR Meeting, Boulder, CO., June 1998

Noto, J., W.J. Schneller, R.B. Kerr, and R.A. Doe, "Nematic Fabry-Perot etalons for ground and space based atmospheric remote sensing," 1997 SPIE Meeting, San Diego, 1997 (1197 Conference Proceedings, 368, 1997)

Noto, J., K.E. Schneller, W.J. Schneller, R.B. Kerr, and R.A. Doe, "Environmental testing of nematic liquid crystals", *Opt. Engin.*, submitted, 1998

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